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AUTHOR Pointer, Richard A.
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ABSTRACT

The document provides an introduction to computer graphics and is intended to be used as reference material to assist the high school drafting student in compiling information. A teletype machine with an acoustical coupler for telephone hookup and a time-sharing Peripherals Corporation flatbed plotter were acquired, and an illustrated programer's guide was prepared as reference for utilization of the system. The guide is intended to provide drafting students with an explanation of the techniques of plotting utilizing a G.E. 225 time-sharing computer and a time-sharing Peripherals Corporation flatbed plotter (TSP212). Section 1 provides a basic understanding of computerized drafting so that plotter output can be generated with minimal Fortran training. Available subroutines and instructions on how to use them are discussed. Six subdivisions cover: glossary of terms, using the time-sharing system, using the time-sharing plotter, subroutines, normal program structures, and sample program with plotter. Section 2 deals with the Fortran makeup of the subroutine available in the system. It provides knowledge of the structure of plotter-oriented subroutines so that, with a knowledge of Fortran, one can expand subroutines to provide a broader library of available subroutines. It is divided into areas on programing and subroutines. (Author/EC)

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FINAL REPORT

PLOTTER RESEARCH

BY

RICHARD A. POINTER

VINCENNES UNIVERSITY

VINCENNES, INDIANA

FEBRUARY 1, 1973

INDIANA STATE DEPARTMENT OF PUBLIC INSTRUCTION

DIVISION OF VOCATIONAL EDUCATION

CE005 442

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I. INTRODUCTION

Early in February of 1971, this project was funded for the purpose of developing a course in computerized drafting for two-year Vocational Drafting Programs.

This endeavor was well justified by the high degree of utilization of the computer by industry both for design and detailing purposes. We placed many students with Bell Telephone Laboratories and other companies such as General Motors, Allison Division, and Ford Motor Company, Inc., who considered a basic knowledge of the computer and plotter highly desireable.

II. STATEMENT OF PROBLEM

The major problem that confronted us was one of great expense for output hardware (plotters) and the limited availability of large enough computers in our high schools and area vocational schools, not to mention the incompatibility of software between different sizes and brands of computers.

We therefore set out to design a course in computerized drafting that was reasonably inexpensive and contained hardware and software that could be made available to any high school drafting program in the state.

III. ANALYSIS AND FINDINGS

A. ANALYSIS

Shortly before the research was begun, Vincennes University

acquired a GE 225 computer with time-sharing capability. This meant that access to our computer could be gained from wherever there was a telephone. This then provided us with the computer availability that we needed to implement our research project.

Once the research proposal was funded, we purchased a teletype machine with an acoustical coupler for telephone hookup and Time-Sharing Periferals flatbed plotter. This particular plotter was selected because of its low cost and its portability.

We received a software package with the plotter that permitted us to do straight-line plotting only. We then had to develop a basic software package that would enable us to do basic drafting applications on the plotter.

B. FINDINGS

After the basic software package was developed it was decided that a student manual or "Programmer's Guide" should be prepared to provide a concise instructional booklet on the utilization of the system and its software. The booklet is, however, only a ready-reference and should not be considered to be a self-instructional document.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

After utilizing this system and the basic software package, several conclusions can be drawn:

1. Industry is becoming more and more desirous of personnel who have even limited exposure to the computer.

2. Given the opportunity and with proper motivation, students will expand significantly upon the basic software package and the plotter capability can grow to astonishing levels over a period of years.

3. With a time-sharing system, the time devoted to this material can vary from one hour to many years. It is limited only by the desires of the user.

4. To our knowledge, no other system is more economical or as flexible.

B. RECOMMENDATIONS

It is our recommendation that this program be made available to other programs throughout the state of Indiana.

We further recommend that there be two types of programs made available.

1. We recommend that a one-day workshop be held to train instructors to utilize the system and the available software. This would provide them with the basic information to introduce their students to this media.

2. Because, however, many students get highly motivated by this media and because many drafting programs have the time and the budget to spend several weeks or months working with this system, we recommend a three-day intensive training session in which the instructors not only learn how to use the system and its software, but also learn the Fortran language and how to do basic Fortran programming so they and their students can attempt to do some original work.

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CTD 260

New Concepts in Drafting

Programmer's Guide

Prepared by

Richard Pointer

Associate Professor

and

Chairman

of

Drafting Department

PROGRAMMERS' GUIDE

FOR

REMOTE TELETYPE AND PLOTTER

USED WITH

VINCENNES UNIVERSITY

TIME-SHARE

COMPUTER

FIRST EDITION

Prepared by:

Richard Pointer

Associate Professor and Chairman

Drafting Department

B.S. I.S.U. 1966
M.S. I.S.U. 1971

January, 1972

Vincennes University

FORWARD

To the User:

This introduction to computer graphics is intended to provide the student of drafting with an explanation of the techniques of plotting utilizing a G.E. 225 timesharing computer and a timesharing Peripherals Corporation flatbed plotter (TSP212) produced by Houston Instrument.

This Programmers' Guide is divided into two parts.

Section #1 deals with a discussion of the available subroutines and includes instructions on how to use them. It is the intent that Section #1 provide a basic understanding of computerized drafting so that plotter output can be generated with a minimum of Fortran training.

Section #2 deals with the Fortran makeup of the subroutine available on our system. It is the intent of this section to provide a basic understanding of the structure of plotter oriented subroutines so that, with a knowledge of Fortran, one can expand our subroutines to provide a broader library of available subroutines.

NOTE: This manual is strictly reference material and is designed to assist the student in compiling information. It is not a self-instructional booklet.

TABLE OF CONTENTS

Section #1:

Division 1 - Glossary of Terms
Division 2 - Using the Time-Sharing System
Division 3 - Using the Time-Sharing Plotter
Division 4 - Subroutines
Division 5 - Normal Program Structure
Division 6 - Sample Program with Plotter

Section #2:

Division 1 - Programming
Division 2 - Subroutines

SECTION #1

DIVISION #1

GLOSSARY

COMPUTER - A device to store and manipulate data.

FORTRAN - A computer language used predominately for scientific applications.

INPUT/OUTPUT - INPUT refers to a method or device used to get information into a computer.
OUTPUT refers to a method or device used to get information out of a computer.

LIBRARY - A method by which the computer stores programs accessible to all users.

PARAMETERS - Refers to the actual value that is entered into a variable name.

PLOTTER - An output device that generates a drawing from x-y movements.

SUBROUTINE - A program written with variable names and no data. Data is added when the subroutine is called.

USER NUMBER - A number assigned to all users for security purposes.

VARIABLE - A fictitious name assigned to a value within a program that is not a constant (always the same value).

DIVISION #2

USING THE TIME SHARING SYSTEM

The Time-Sharing System consists of a GE-225 computer with a DATANET-30 and a number of input/output stations (currently, models 33 and 35 teletypewriter machines). Individuals using the input/output stations are able to "share" the use of the computer with each other in such a way as to suggest that each has sole use of the computer. The teletypewriters are the devices through which the user communicates with the computer.

The Keyboard

The teletypewriter keyboard is a standard typewriter keyboard for the most part. There are three special keys the user must be familiar with.

RETURN — The RETURN key is located at the right-hand end of the third row of keys, and does more than act as an ordinary carriage return. The computer ignores the line being typed until this key is pushed.

CTRL — The CTRL (control) key is located at the left-hand end of the third row of keys. When it is pressed along with the X key, the computer deletes the entire line being typed. This also acts as a carriage return.

The backwards arrow key is the shift of Ø. It is used to delete the character or space immediately preceding the -. If this key is pressed N times, the N preceding characters or spaces will be deleted.

Examples:

ABCWT - - DE appears as ABCDE when RETURN is pushed.

AB C - - CDE appears as ABCDE when RETURN is pushed.

Some languages available on the Time-Sharing System use the three characters , , and . They are located on the keys L, K, and M, respectively, when either SHIFT key is pushed.

Teletypewriter Operation With Direct Telephone Line

Besides the keyboard itself there are four control buttons necessary to operate the machine.

Button	Location	Function
ØRIG	Leftmost of six small buttons on the right	Turns on the teletypewriter and connects it to the phone line.
CLR	Next to ØRIG	Turns off the teletypewriter and disconnects the phone circuit
LØC LF	Left of the space bar on Model 35 Teletypes only	Feeds paper to permit tearing it off
BUZ-RLS	Rightmost of six small buttons on the right	Turns off the buzzer that signals a low paper supply

If the teletypewriter is on a direct line to the computer, pushing the ØRIG button is all that is necessary to connect up with the computer. To disconnect from the computer, type GØØDBYE or BYE. If that fails, push CLT.

In order to connect with the computer from a teletypewriter not on a direct line:

* Push the ØRIG button and wait for the dial tone.

* Dial one of the numbers at the Time-Sharing Center.

In order to disconnect, type GØØDBYE or BYE, and if that fails, push CLR.

The Keyboard Required Statements at Sign On

Once the teletypewriter is connected to the computer, push the "HERE IS" button. Remember that all typed lines must be followed by a carriage return (RETURN). The machine then asks for certain information which the user supplies by typing the information when asked for it, and following each response with a carriage return.

First, it asks for the user's number, which is assigned by the Time-Sharing Center. Next it asks for the system to be used (FORTRAN (FOR). Then it will ask whether it is a new or old program the user will be working on. A new program is one which the user is about to begin, while an old program is one which has been saved in memory for future use.

TELETYPEWRITER OPERATION WITH A TELEPHONE AND AN ACOUSTICAL COUPLER

To connect the teletypewriter to the computer you must first turn the power switch on the lower right side of the teletype panel to "LINE", this turns on the teletype. You then pick up the telephone and dial the telephone number for the computer. When you hear a high pitched sound, place the receiver in the acoustical coupler with the cord facing the top of the teletype. When the green light on the teletype comes on you are ready to begin.

NOTE: The green light is your coupling indicator and if it goes out, you have lost contact with the computer and need to call it up again.

Finally, it will ask for the new or old program name. After the machine types READY the user may begin with his new program or pick up where he left off on his old program. A typical HELLO sequence follows: (The underline indicates information typed by the user.)

HELLO or punch the "HERE IS" button

USER NUMBER -- 999999 R

SYSTEM -- FOR R

NEW OR OLD -- NEW R

NEW PROBLEM NAME -- M36-2 R

READY

NOTE

All programs should be punched off line on punch tape and when all typing errors are omitted, they can be inputted into the system.

When the program is inputted into the system, type SAVE ®, this tells the computer to retain your program.

Now you are ready to type RUN ®, this runs your program. Any errors noted at this time can be corrected simply ty retyping the corrected line number and its content and R, then type SAVE ® when the computer prints ready.

When a lengthy program is completely clean and debugged, you may run it in binary which sets up an object deck and shortens the run time tremendously. This method is of no value, however, until your program is completely debugged. You store in binary by typing RNS ®. After it runs once, your object deck is on file and future runs are made by typing RNB ®.

GENERAL ELECTRIC COMPUTER TIME SHARING SERVICE
SYSTEM COMMANDS

COMMANDS	USE
DIRECTIVE	
Control @	To cause the computer to stop whatever it is doing with the program when printing is occurring.
BYE	To disconnect from the System.
GOODBYE	To disconnect from the System.
HELLO	To address the System or to change user number.
NEW	To introduce a new program and destroy the working copy of the current program.
OLD	To retrieve from saved store a previously saved file and destroy the working copy of the current program.
Return	To terminate a program line, cause the System to take action based upon input provided, and act as a normal carriage return.
RUN	To compile and execute a program.
SAVE	To save permanently the working copy of a program.
SCRATCH	To eliminate from the working copy of a program everything but the program name.
STOP	To cause the computer to stop whatever it is doing with the program except when printing is occurring.
UNSAVE	To release and destroy a previously saved program.
User Number	Six characters that identify the user to the System.
EDIT	
Alt Mode or Escape or Control with X	To delete an input line as if nothing had been typed.
Arrow ( )	To erase the last character(s) typed. SHIFT key must also be depressed.

EDIT DELETE	To erase portions of a program.
EDIT EXTRACT	To retain portions of a program.
EDIT MERGE	To combine saved files into working store and to resequence line numbers.
EDIT RESEQUENCE	To resequence line numbers in program in working store.
LIST	To list the current working copy of a program.
LIST -- X	To list the current working copy of a program beginning at line X (X=1-5 digits).
RENAME	To change program name but not working copy contents.

INFORMATIVE

CATALOG	To list a user's catalog of saved programs.
LENGTH	To request the number of characters in working copy of program.
STATUS	To request status of user on system.
TTY	To learn which channel of the DATANET-30* is being used for your connection and to print current user number, problem name, system name, and status.

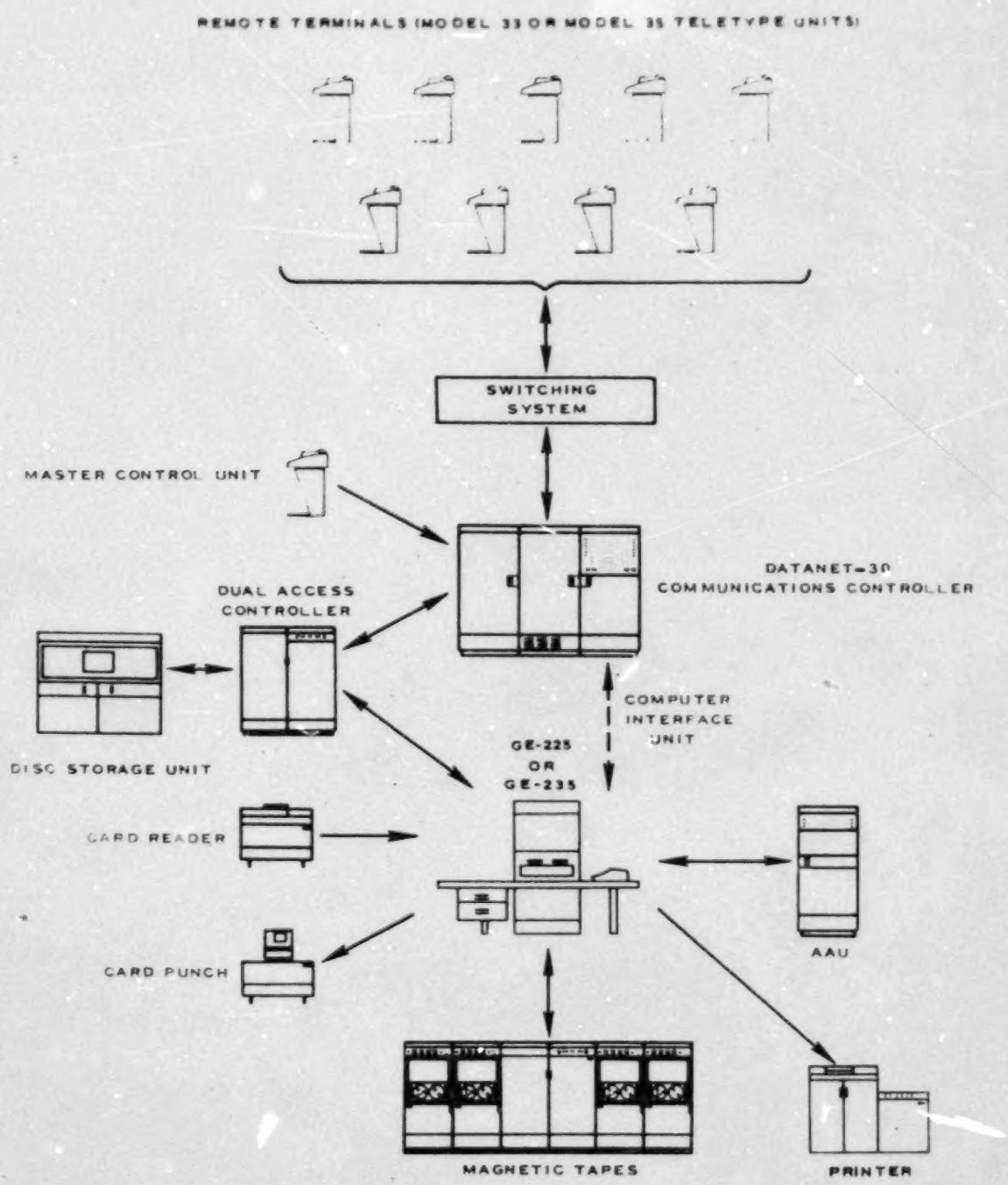
MODE

ALGOL	To denote programming language.
BASIC	To denote programming language.
FORTRAN	To denote programming language.
KEY	To reset terminal operation to normal after reading in paper tape.
SYSTEM	To change name of the system under which you are working.
TAPE	To inform the System that paper tape will be read in.

. Special key on Teletype unit

* DATANET is a Reg. Trademark of the General Electric Company

EXHIBIT A



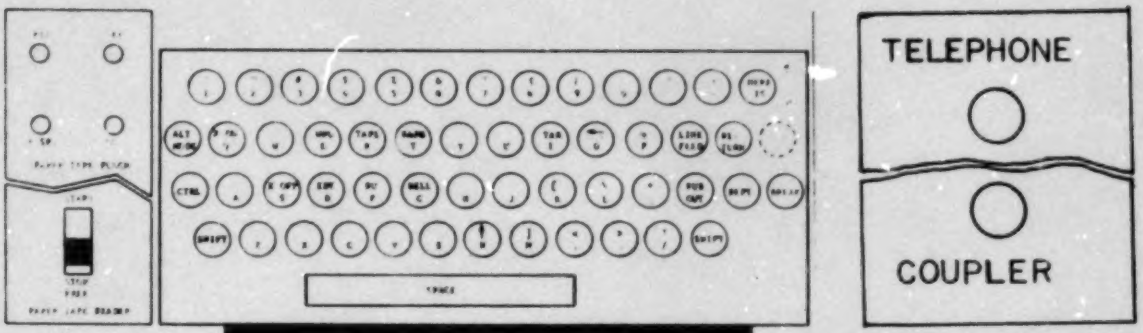
GE-200 Series Time-Sharing System Configuration

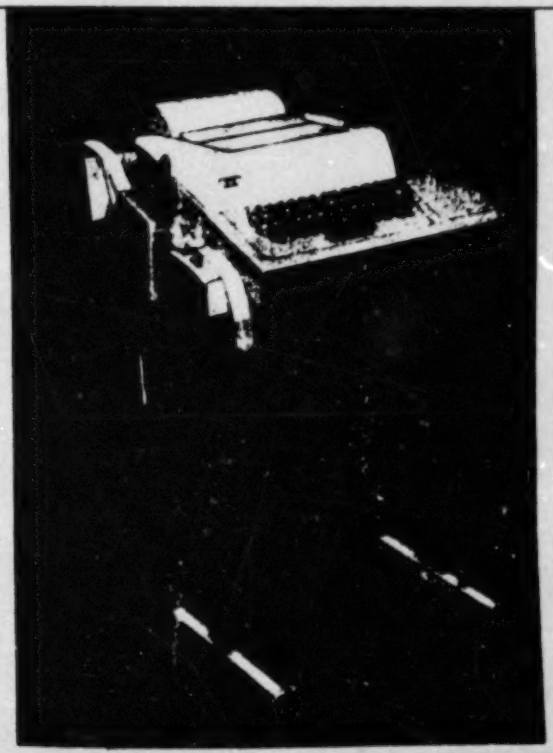
EXHIBIT B

MODEL 33 TELETYPE UNIT

The principal parts of the Teletype unit are the Control Unit, Keyboard, Paper Tape Punch (optional), and Paper Tape Reader (optional).

Control Unit,
Keyboard,
Paper Tape Punch (Optional), and
Paper Tape Reader (Optional)





DIVISION #3

OPERATION OF PLOTTER

Controls

ON/OFF - Switches line power to the Plotter.

ZERO - Pushbutton, when pressed, positions the pen at the "zero" point (lower left-hand corner of plotting area) on the X-Y recorder unit as set with the ZERO X and ZERO Y controls. Refer to Figure 1.

ZERO X - Sets the horizontal position of the "zero" point on the X-Y recorder unit.

ZERO Y - Sets the vertical position of the "zero" point on the X-Y recorder unit.

FULL SCALE - Pushbutton, when pressed, positions the pen at the "full scale" point (upper right-hand corner of plotting area); that is, the limiting distance the plotter pen may travel from the "zero" point. Refer to Figure 1.

FULL SCALE X - Sets the horizontal position of the "full scale" point on the X-Y recorder unit.

FULL SCALE Y - Sets the vertical position of the "full scale" point on the X-Y recorder unit.

PLOT - Pilot light indicates when system is in plot mode.

PRINT - Pilot light indicates when system is print mode.

RECORD/LOAD (TSP-212 only) - Setting switch to LOAD position (ON/OFF switch at ON) causes recorder pen carriage to move to right margin for loading or annotating chart paper. RECORD position conditions recorder for normal operation.

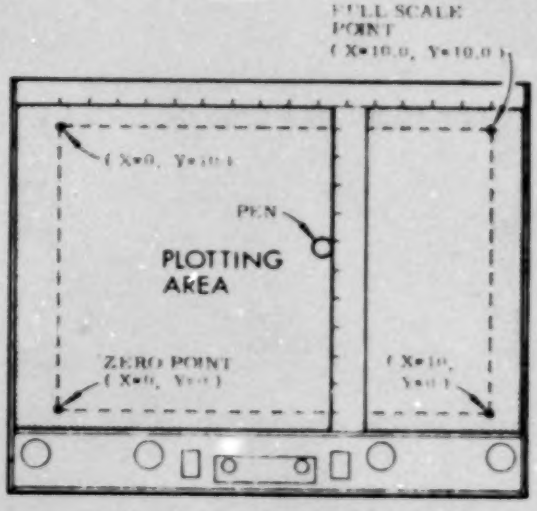


Fig. 1 Plotting Area (Inside Dashed Outline) Established by Means of ZERO and FULL SCALE X and Y Controls

Operating Procedure

The time share terminal to which a TSP-212 is connected will operate normally when the ON/OFF switch on the TSP-212 is in the OFF position. When software requiring the plotting of data is to be used, however, set the ON/OFF switch at ON. The plotter control until will then monitor the computer output and direct operation of the terminal printer and X-Y recorder as required by the computer.

Under computer control, the TSP-212 is practically self-operating. The controls are primarily to establish the plotting area within which the X-Y recorder pen will plot the information required. Once adjusted, they seldom need to be reset unless the plotting area is to changed.

Figure 1 shows a plotting area established on the X-Y recorder. The X and Y coordinates for the four corners are given in "plotter units" and are always the same, no matter what the size of the plotting area. The area is set up by establishing two points, the "zero" and "full scale" points, as follows (all controls mentioned are on the TSP-212 unless otherwise specified):

1. Set the ON/OFF switch at ON, and if a separate X-Y recorder unit is used, turn on power to that unit as well.

2. Paper is loaded into the recorder in two different ways.

   "B" size (11 x 17) is loaded by simply slipping the sheet onto the surface of the plotter under the beam. Move the sheet down and to the left against the bottom and left guide so as to properly register the sheet. The surface of the plotter is perferated, and when on, provides a vacuum to hold the sheet in place.

   "A" size (8 1/2 x 11) is loaded in the same manner as "B" size except a plastic shield is placed on the plotting surface first. The shield provides identifying marks to provide for proper alignment. The shield is provided for three reasons. First, it insures full vacuum for the smaller sheet. Secondly, it serves as a positioning guide. Thirdly, the shield protects the open surface areas of the plotter from pen markings.

3. Pen loading is done by slipping the disposable unit into the clips on the beam holder. The pen unit has slots for the clips to grip on and the ink cap must be removed before placing it into position.

NOTE:

Caution must be taken not to drop the pen as it may fall through the opening at the bottom of the unit and lodge in the component compartment.

4. Set the location of the plotting area "zero" point. To do so, hold in the ZERO pushbutton while adjusting first the ZERO X control and then the ZERO Y control to bring the writing device to the desired location for the lower left corner of the plotting area.

5. Set the location of the plotting area "full scale" point. To do so, hold in the FULL SCALE pushbutton while adjusting first the FULL SCALE X control and then the FULL SCALE Y control to bring the writing device to the desired location for the upper right corner of the plotting area. The plotting area is now established.

NOTE:

The locations of the "zero" and "full scale" points can be checked at any time while the plotting system is turned on. Press the ZERO button to set the writing device at the "zero" point; press the FULL SCALE button to set the writing device at the "full scale" point.

DIVISION #4

INTRODUCTION

Before you begin writing program, a brief explanation of the structure of subroutines is necessary.

Subroutines are program written with variable names and constants; no data is included. In order to use a subroutine we CALL the subroutine and replace the variable names with our parameters (values).

Example of subroutine (form) = call plot (X, Y, IP)
Example of subroutine call (use) - call plot (7.5, 5., 13)

One must also understand the difference between two types of variable names: fixed point (integer) and floating point (real).

Any variable name whose first character begins with I, J, K, L, M, or N is considered to be a fixed point variable, ie., integer, and the numeric value written will not include a decimal point. See CALL plot (X, Y, IP), the value of "IP" is "13# and is written with no decimal point.

Any other variable name not beginning with I, J, K, L, M, or N is considered to be a floating point variable, ie., real and must include a decimal point. See CALL PLOT (X, Y, IP) the value of "X" is "7.5" and is written with a decimal point.

PLOT LINES

The PLOT subroutine plots a straight line.

Call PLOT (X, Y, IP)

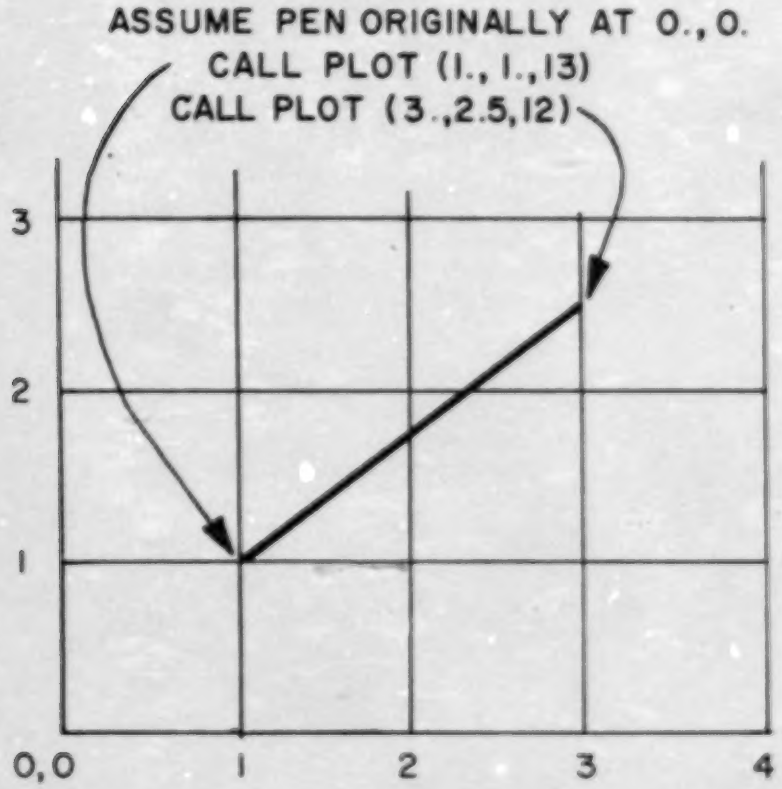
(X, Y) are the coordinates of the point you wish to move to.

(IP) is the pen position indicator.

NOTE:

a. If (IP) is 12, a line will be plotted from the present position to (X, Y).

If (IP) is 13, no line will be plotted from the present position to (X, Y).



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4-2

RECTANGLES

The RECT subroutine plots rectangles.

Call RECT (X, Y, H, W, AN, IP).

(X, Y) are the coordinates of the lower left hand corner.

(H) is the height of the rectangle.

(W) is the width of the rectangle.

(AN) is the angle that the base makes with the (+X) axis measured counter-clockwise.

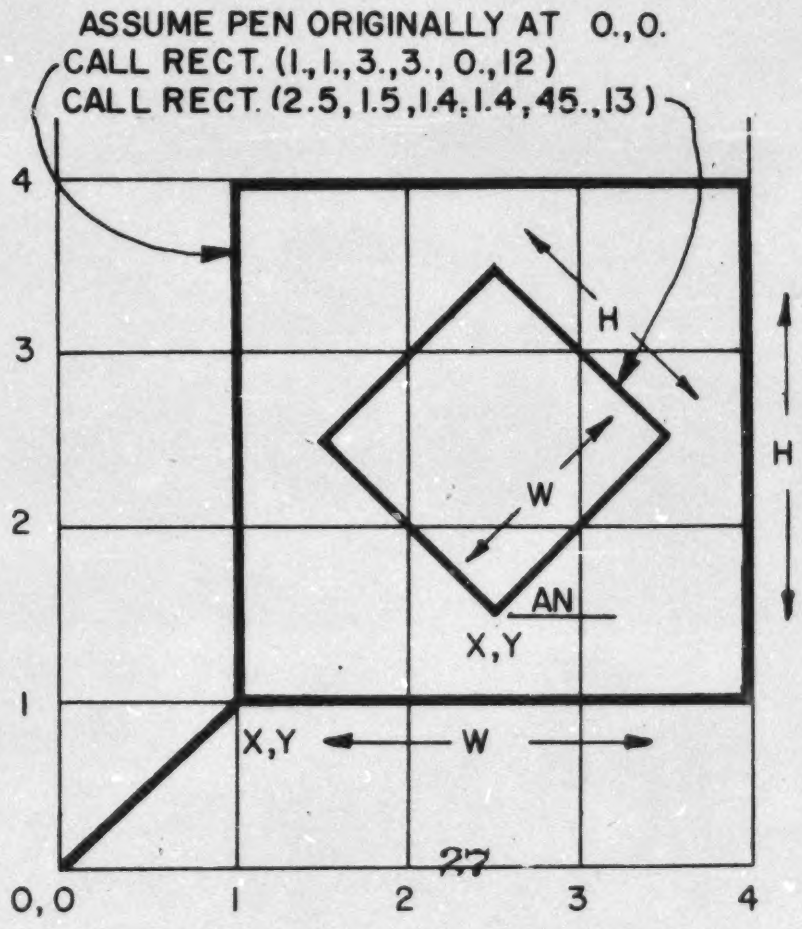
(IP) is the pen position indicator.

NOTES:

a. If (AN) = 0.0, the base will lie on the (+X) axis.

b. If (IP) = 12, a line will be plotted from the present position to (X, Y).

If (IP) = 13, no line will be plotted from the present position to (X, Y).



CENTER LINES

The CLINE subroutine plots a center line.

Call CLINE (X, Y, EX, EY).

(X, Y) are the coordinates of the beginning point.

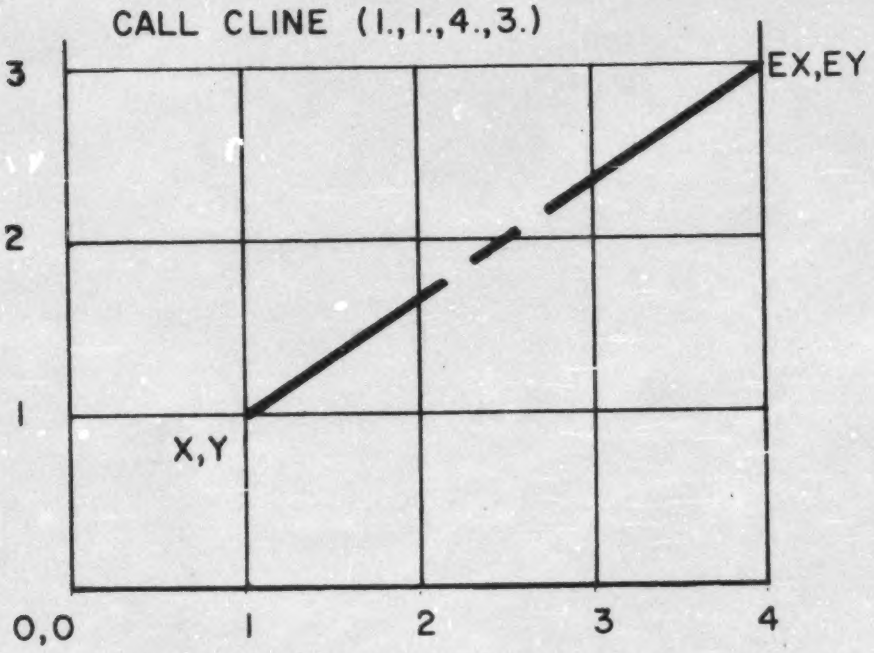
(EX, EY) are the coordinates of the ending point.

NOTE:

a. The short dashes and spaces are .125 inches.

b. The long dashes are approximately 1.250 inches long.

c. The total length must be equal to or greater than 2.375 inches.



I
4-4

DASHED LINES

The DASHL subroutine plots a dashed line.

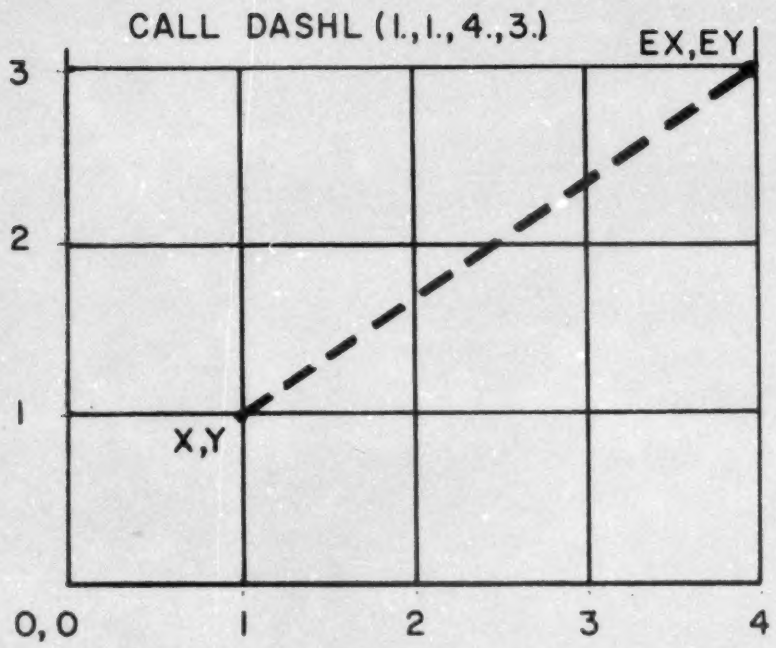
Call DASHL (X, Y, EX, EY).

(X, Y) are the coordinates of the beginning point.

(EX, EY) are the coordinates of the ending point.

NOTE:

a. The dashes and spaces are approximately .125 inches long.



LEADER LINES

The LEADR subroutine plots a leader line.

Call LEADR (X, Y, A, DL).

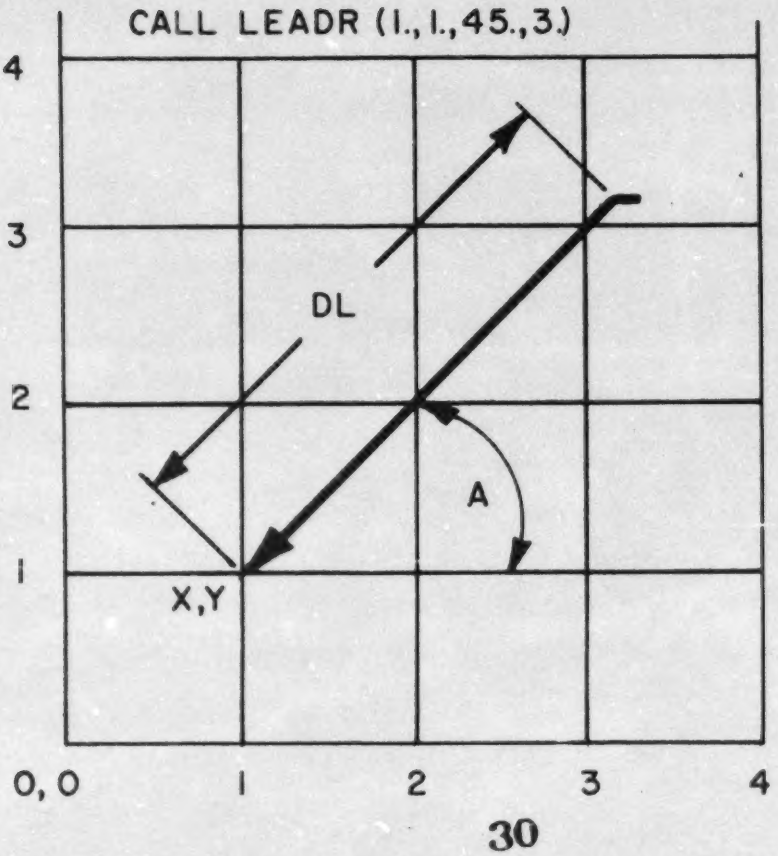
(X, Y) are the coordinates of the tip of the arrowhead.

(A) is the angle that the leader makes with the (+X) axis measured counter-clockwise.

(DL) is the length of the leader line.

NOTE:

a. The leader can be plotted at any angle and terminates with a .125 inch horizontal line.



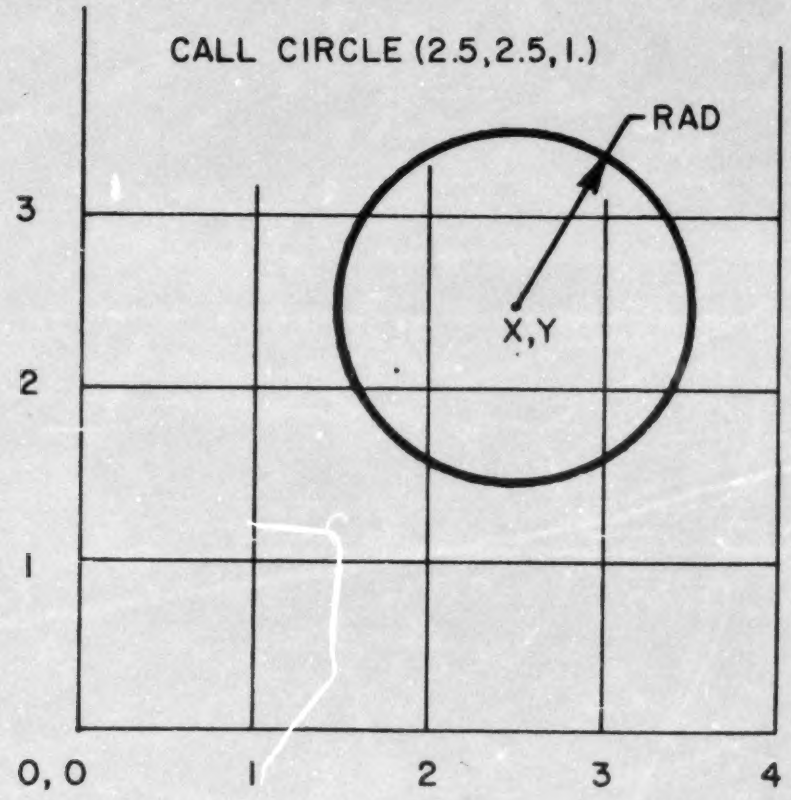
CIRCLE

The CIRCLE subroutine plots a circle.

Call CIRCLE (X, Y, RAD).

(X, Y) are the coordinates of the center of the circle.

(RAD) is the radius of the circle.



ARC

The ARC subroutine plots a portion of a circle.

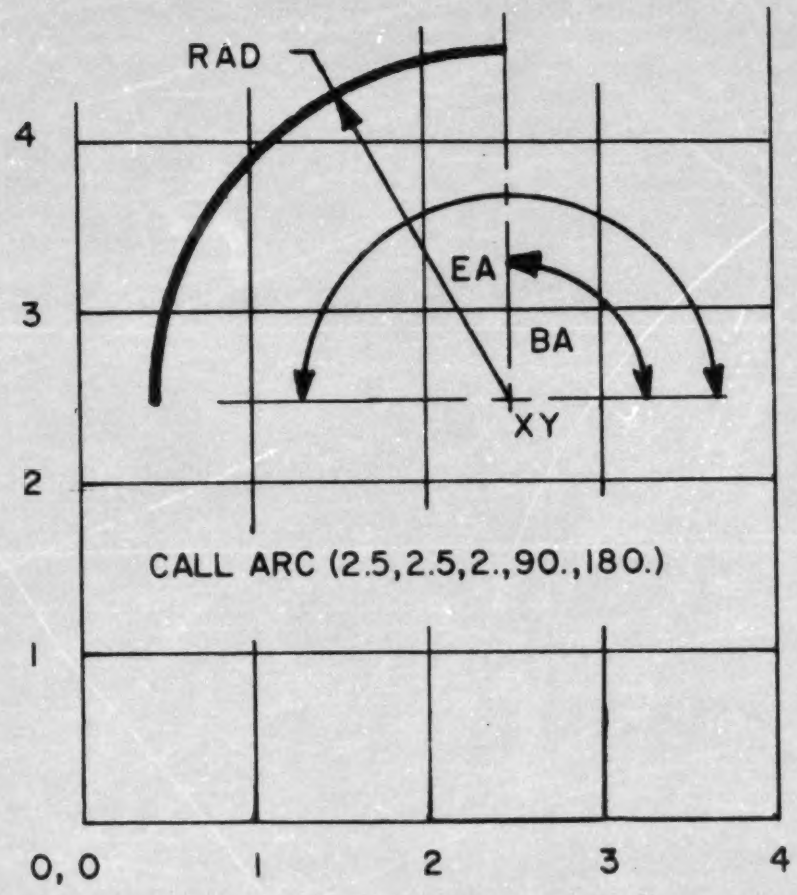
Call ARC (X, Y, RAD, BA, EA).

(X, Y) are the coordinates of the center of the arc.

(RAD) is the radius of the arc.

(BA) is the angle that the beginning point makes with the (+X) axis, measured counterclockwise.

(EA) is the angle that the ending point makes with the (+X) axis, measured counterclockwise.



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4-8

PLOT SYMBOLS

The Symbols subroutine plots characters and numbers.

Call Symbol (X, Y, HTI, THETA, NN, "WOR", "D").

(X, Y) are the coordinates of the lower left hand corner of the first letter.

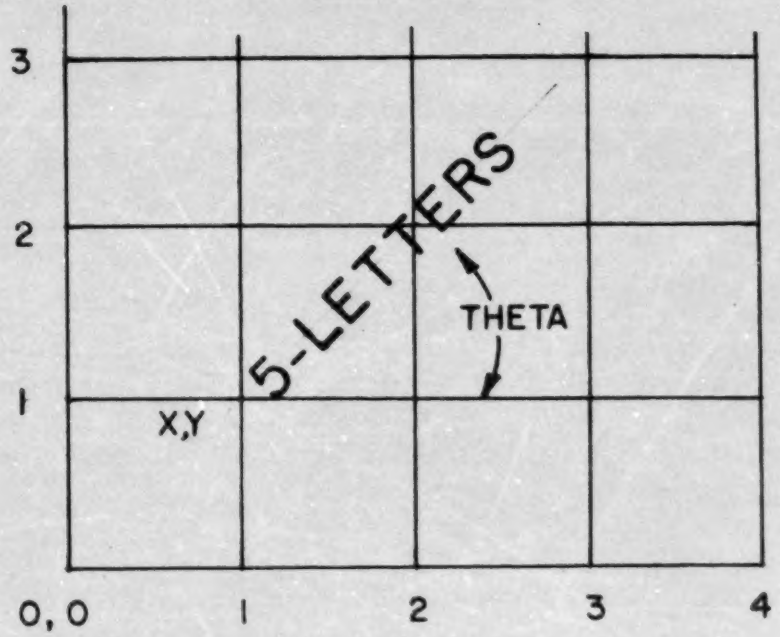
(HTI) is the height of the characters to be plotted.

(THETA) is the angle that the characters make with the (+X) axis, measured counterclockwise.

(NN) is the number of characters and spaces to be plotted.

"WOR", "D" - In the space following "NN" we type out the character we wish to plot. They must, however, be typed in sets of three and set in quotes and separated by commas. The last set can be three, or less, characters.

Call Symbol (1., 1., .25, 45., 9, "5-L", "ETT", "ERS")



PLOT DIMENSION LINES

The DIMENL subroutine plots a dimension line and is terminated by arrowheads.

Call DIMENL (X, Y, A, DL).

(X, Y) are the coordinates of the tip of the left hand arrowhead.

(A) is the angle that the dimension line makes with the (+X) axis, measured counterclockwise.

(DL) is the length of the dimension line measured from the tip of one arrowhead to the tip of the other arrowhead.

NOTE: The arrowhead is approximately 3/16th inches long.

If the value of the dimension is .5 inches or less, the dimension line is drawn with the arrowheads facing each other as is illustrated in EX. B.

NORMAL PROGRAM STRUCTURE

```
        Signifies this is a comment statement and not part of the program
           One space
              Identify program purpose

100 C   Program to plot lines

        Line number (every line must be numbered)
           It is suggested to start out at 100 and count by tens to avoid conjestion.

        Identify variable names
110 C   (X, Y) are coordinates of beginning point

        Use an input statement to debug program
120     INPUT, X, Y, IP


        Convert input statement to subroutine statement if desired after debugging
120     Subroutine plot (X, Y, IP)


        Converts user unit to plotter unit so units on plotter surface correspond to
           plot dimensions.
130     CALL OFFSET (0., 1.5, 0.,1.)

        Program Body (All programs must use this library function to get plot capability

180     $Use Plots***


        Converts from print mode to plot mode so plotter can function.
290     CALL TTY


        All subroutines used must be called up from library using $use (name)
300     $ use PLOT


        for input statement
310     STOP


        for subroutine
310     RETURN


        terminates program
320     END
```

SECTION #2

PLOTTER SYSTEM CONVENTIONS

Plotter and User Units

As shown in Figure 2, the plotting area within which plotting will be done is defined by the positions of the zero and full scale points, as set with TSP ZERO and FULL SCALE X and Y controls. The coordinates of these points are always X=0, Y=0 for the zero point, and X=10, Y=10 for the full scale point. The units for the coordinates are arbitrary and are associated only with the plotting device. They are referred to, therefore, as plotter units. All points to be plotted will fall within the plotting area, and their coordinates will be within the ranges X=0 to X=10 and Y=0 to Y=10, in plotter units.

From the standpoint of the user, it is easier to handle information to be plotted by using the units associated with the information (for example, dollars, hours, radians, etc.). Such units are referred to as user units. One function of the plotter subroutines used with the TSP 212 is to translate any data identified as being in user units into a form that can be acted upon by the plotter control unit.

To illustrate the relations between user units and plotter units, consider the case in which the functions Y=sin X is to be plotted. Y and X are in user units, Y representing the sine of an agle X, which in this example is in radians.

Before the program can be written, the plot must be planned. Since the value of sin X ranges from -1 to +1, the Y -axis in user units extends from -1 to +1. The range of angles to be plotted extends from - to + radians. The X-axis in user units, therefore, also ranges from - to + radians. Figure 4-1 shows the plotting area and the correspondence between user units and plotter units. The coordinates of the zero point and the full scale point, in user units, are the only information needed to establish the relation.

Granularity and Step Value

When a line is to be plotted, the distance between the points plotted to define the line must be smaller for a line with sharp curves than for one with gradual curves. In other words, for two lines of the same length, it is necessary in order to obtain a given accuracy to calculate more points for a sharply curved line than for a gradually curving or straight line. This is done by reducing the granularity of the plot (that is, by increasing the frequency with which the points to be plotted are calculated).

In the case of the function Y=sin X, from the example used earlier, large granularity could result in a misleading representation of the sine curve. The programmer, therefore, would make the granularity (or difference between successive values of X) small enough to result in a more accurate representation of the function (See Figure 3). He would program this difference just as he would if he were planning to print out a tabulation of the values of sin X.

There is a limit to the effect a reduction in granularity will have on improving the accuracy of a presentation. Beyond this limit, any further reduction in granularity increases the computer time required to calculate the coordinates of additional points and results in higher costs, but does not improve the accurary of the plot. With experience, the programmer will become able to judge effectively what granularity is optimum for a desired accuracy of presentation. Where experience is lacking, it is generally better to make the granularity somewhat large at first, then decrease it until the presentation is satisfactory.

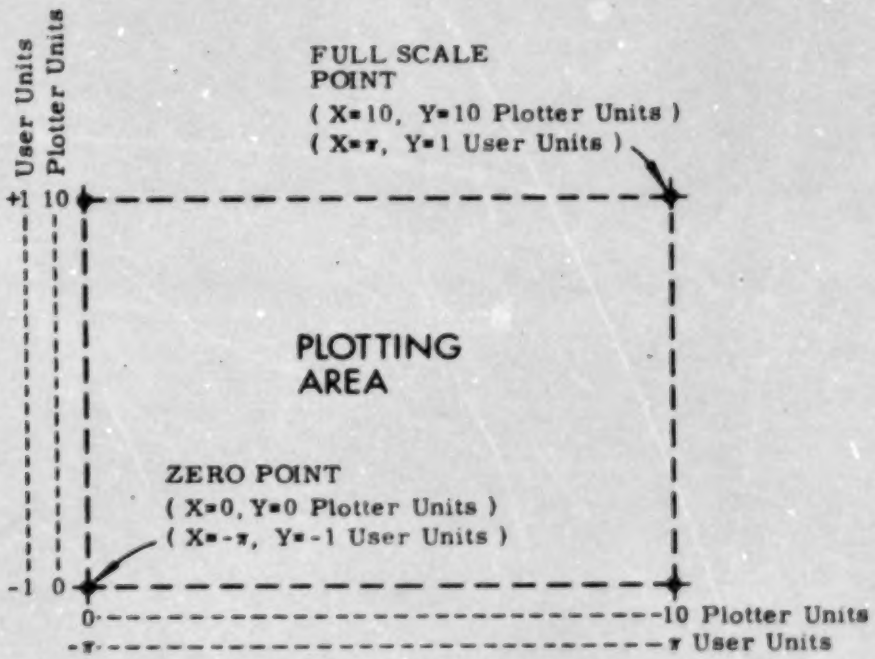


Figure 2. Plotting Area for Plotting Y=sin X of X Ranging from - to + Radians. Correlation between User Units and Plotter Units is Shown.

For X-Y recorders, which respond more slowly to data signals from the computer, the programmer must take into account the effects of the slower response and the inertia of the recorder system. These effects are manifested in several ways:

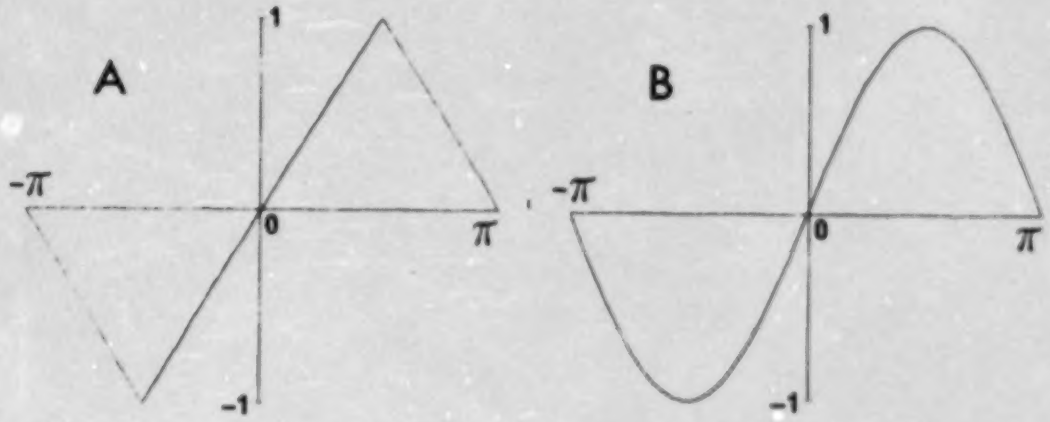
1. The recorder pen tends to draw a curve to fit the data points.

2. Once curvature is established, the system tends to maintain curvature.

3. The pen may not be able to keep pace with the rate at which the time share system supplies data to be plotted if the granularity is made too large.

The inability of the pen to plot transmitted data when the granularity is too large is an effect of the mechanics servo characteristics of the pen drive system. The usual recorder pen cannot draw a reasonable plot at high speed when distances between points are large, even though the plot consists merely of straight lines. The rate of data input is too fast for the pen drive system.

To overcome this problem the plotter driver subroutine automatically limits the maximum step value between points to be plotted. In this subroutine, the maximum step value may be anything the programmer selects, from 10.0 to 0.0, where 10 represents a full scale step size (10 plotter units), in which case the plotting takes place.



Y=SIN, X, X INCREMENTED BY /2 Y=XIN, X, X INCREMENTED BY 2 /50

Figure 3 Effects on Plot Resulting from Selection of Granularity Value.

The step size comes into effect only when the figure to be plotted has long straight lines which are designated in the normal program by the coordinates of the end points, only. The subroutine automatically breaks down such long lines into short segments no longer than the maximum step value. For normal plotting with a recorder, a limiting step value of 1.0 is recommended. Other step values may be found useful under certain conditions.

The plotter driver software is designed to facilitate changing the step value so that the user may trade accuracy for speed according to his needs, i.e., he may opt for very fast, but less accurate plots for first approximations or for slower more presentable plots for final presentation. The subroutine for establishing the step value is generally called in the initialization portion of the program. If not called, the stop size is set to a default value of 1.0.

Software Description

The following sections describe the plotter-driver software for use with the Model TSP-212 and, through examples, demonstrate plotter programming principles.

Programming to plot a function is demonstrated using the example (Fig. 4) in which Y=sin X is plotted for values of X ranging from - to + . The program is listed first in FORTRAN.

FORTRAN Programming

All statement numbers given for the FORTRAN example refer to the listing in Figure 4.

Initialization consists of using appropriate statements to enter the coordinates of the "zero" and "full scale" points in both plotter and user units. Also, the required granularity and limiting step value are set and other variables are defined as required.

The plotting area for the sine function, in both user and plotter units, is shown in Figure 4. With this arrangement, the X- and Y- axes in user units cross in the center of the plotting area, as shown in Figure 3. The axes are plotted in addition to the sine curve. Furthermore, in order to obtain a smooth curve, the number of points plotted on the sine curve is made relatively large. The program is initialized as follows:

The "zero" and "full scale" points are entered, along with the relationship of user to plotter units, in the OFFSET subroutine. This subroutine is brought into effect in statement 190. The arguments for this statement may be assigned in earlier statements or may be assigned numerical values directly. For convenience, variable names are used in the example and values are assigned beforehand in statements 110 through 150. Fifty points are to be plotted. The coordinates of these points are calculated by adding a constant to the value of X used in the previous calculation of sin X. This constant (the granularity) is 1/50 times 2 , the range of X, and is established in statement 160.

The program is now initialized. No maximum allowable step size is indicated specifically by a statement calling the STEP subroutine. Omission of this statement from a FORTRAN program implies a maximum allowable step size of 1 plotter unit (1/10 of full scale). Whenever the separation between two data points to be plotted exceeds this distance, the plotter software will automatically calculate and plot points on a straight line between the two data points, at intervals of 1 plotter unit.

Plotting Points

Whenever the plotter writing device is to be moved, the subroutine PLOT is called in the following statement:

```
CALL PLOT (X, Y, IP)
```

The X-axes for the sine function in the example is plotted using statements 230 and 240. Statement 230 positions the pen at X=0, Y=5, in plotter units. The pen is up so that it does not write while moving to that position. Statement 240 moves the pen down onto the paper, then full scale in the horizontal direction to produce the X-axes. The Y-axes is plotted with statements 280 and 290.

Initialization

1. Use the following statement to relate user units to plotter units.

   CALL OFFSET (XMIN, DX, YMIN, DY)

   where: XMIN, YMIN = coordinates of "zero" point in user units

   $$DX = \frac{\text{Range of X in user units}}{\text{Range of X in plotter units}} = \frac{XMAN - XMIN}{10}$$

   $$DY = \frac{\text{Range of Y in user units}}{\text{Range of Y in plotter units}} = \frac{YMAX - YMIN}{10}$$

   XMAN, YMAX = coordinates of "full scale" point in user units.

NOTE: If OFFSET is not called in the program, the values of XMIN and YMIN are 0.; DX and DY are 1.0.

2. If necessary, use the following statement to establish limiting step size.

   CALL STEP (G)

   where: G = limiting step value between points (in plotter units). Value of G may range from 0.0 to 10.0, where 10.0 - full scale. For X-Y recorders, a value of 1.0 is recommended for normal plotting.

NOTE: 1. If STEP subroutine is not called, limiting step size is 1.0.

2. This subroutine call should appear as early as possible in the program.

Plotting

Use the following statement to put the plotter control unit into plot mode and plot a point.

CALL PLOT (X, Y, IP)

where: X, Y = coordinates of point to be plotted in units determined by value of IP, IP is a number which determines units of X and Y, and commands recorder pen to move in either the up or down position as follows:

IP = 2 signifies "move with pen down, X and Y plotter units"
IP = 3 signifies "move with pen up, X and Y in plotter units"
IP =12 signifies "move with pen down, and X and Y in user units"
IP =13 signifies "move with pen up, X and Y in user units"

Transferring from Plot to Print Mode

Use the following statement to make sure all data points are plotted and change the plotter control unit to the print mode:

```
CALL TTY
```

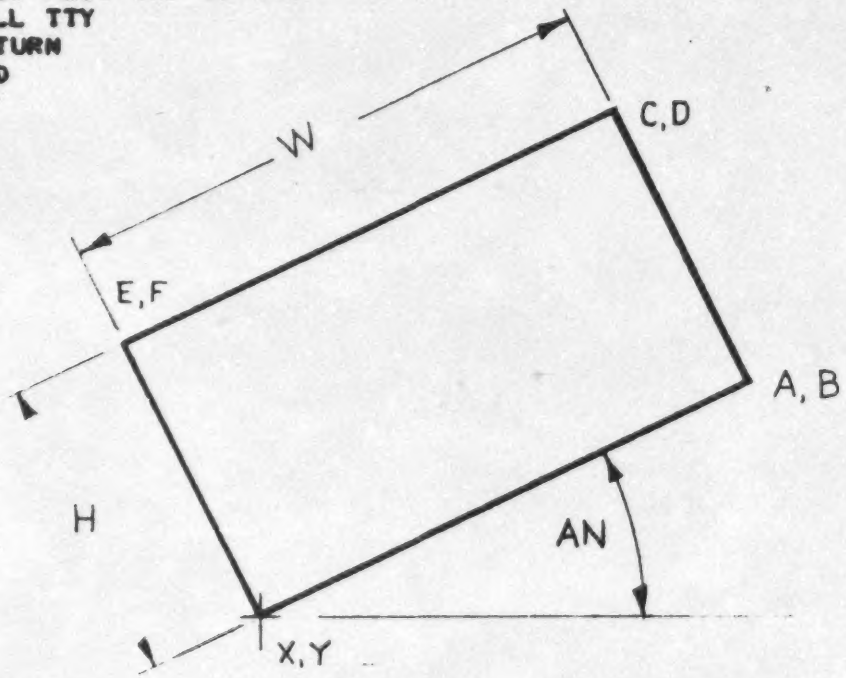
```
100C    PLOT OF SIN(X) VS. X
110     DATA Z, PI/0.0,3.14159625/
120     XMIN=-PI
130     DX=2*PI/10
140     YMIN=-1.
150     DY=.2
160     G=2.*PI/50
190     CALL OFFSET (XMIN, DX, YMIN, DY)
230     CALL PLOT (Z, 5.0, 3)
240     CALL PLOT (10., 5.0, 2)
280     CALL PLOT (5., 10., 3)
290     CALL PLOT (5., Z, 2)
330     X=XMIN
340     CALL PLOT (X, SIN(X), 13)
390 10  Y=SIN(X)
400     CALL PLOT (X, Y, 12)
410     X=X+G
420     IF (X.LE.PI) GO TO 10
470     CALL PLOT (Z, 5, 3)
480     CALL TTY
490     STOP
500     END
```

Once the axes have been plotted, the pen is raised and moved to the starting point for plotting the sine function (statements 330 and 340). Here user units are used (note the argument 13 in statement 340). Plotting of the sine function in user units can now begin, and is accomplished by means of a program loop (statements 390 through 420) in which values of X are incremented by the value of G assigned in the initialization portion of the program. The pen is then raised and moved to the left side of the chart in readiness for the next plot (statement 470). Here plotter units are used.

Fig. 4 Listing for FORTRAN Program for Plotting Y=sin X.

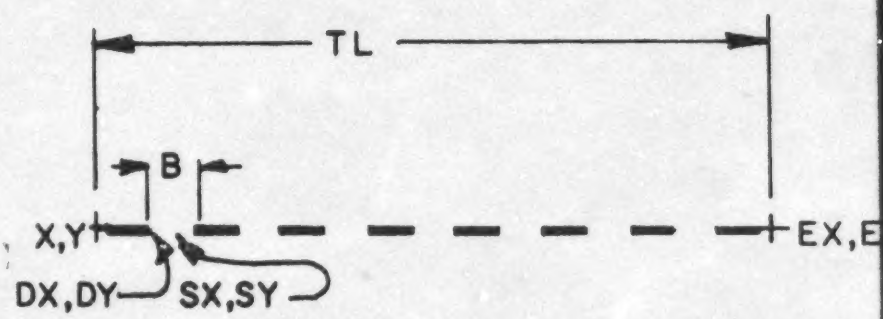
Returning to Print Mode – Once the desired function has been plotted, the plotter control unit must be returned to the print mode so that any further communication will be displayed on the time share terminal printer. This is done in statements 480 and 490.

```
100C PROGRAM TO PLOT A RECTANGLE
101C (X,Y) ARE THE COORDINATES OF THE LOWER LEFT HAND CORNER.
102C (H) IS THE HEIGHT.
103C (W) IS THE WIDTH.
104C (AN) IS THE ANGLE THAT THE BASE MAKES WITH THE (+X) AXIS
105C + MEASURED COUNTERCLOCKWISE.
106C (IP) IS THE PEN POSITION INDICATOR, (12) DOWN (13) UP
107C + MOVEMENT TO THE LOWER LEFT HAND CORNER.
110 SUBROUTINE RECT(X, Y, H, W, AN, IP)
120 CALL OFFSET(0.,1.5,0.,1.)
130 CALL PLOT (X, Y, IP)
140 AR = .01745 * AN
170 A = X + (W * COS (AR))
180 B = Y + (W * SIN (AR))
190 CALL PLOT (A, B, 12)
220 C = A - (H * SIN (AR))
230 D = B + (H * COS (AR))
250 E = C - (W * COS (AR))
260 F = D - (W * SIN (AR))
265 CALL PLOT (C,D,12)
270 CALL PLOT (E, F, 12)
280 CALL PLOT (X, Y, 12)
290 CALL TTY
310 RETURN
400 END
```



(AR) is the angle (A) in the radians.

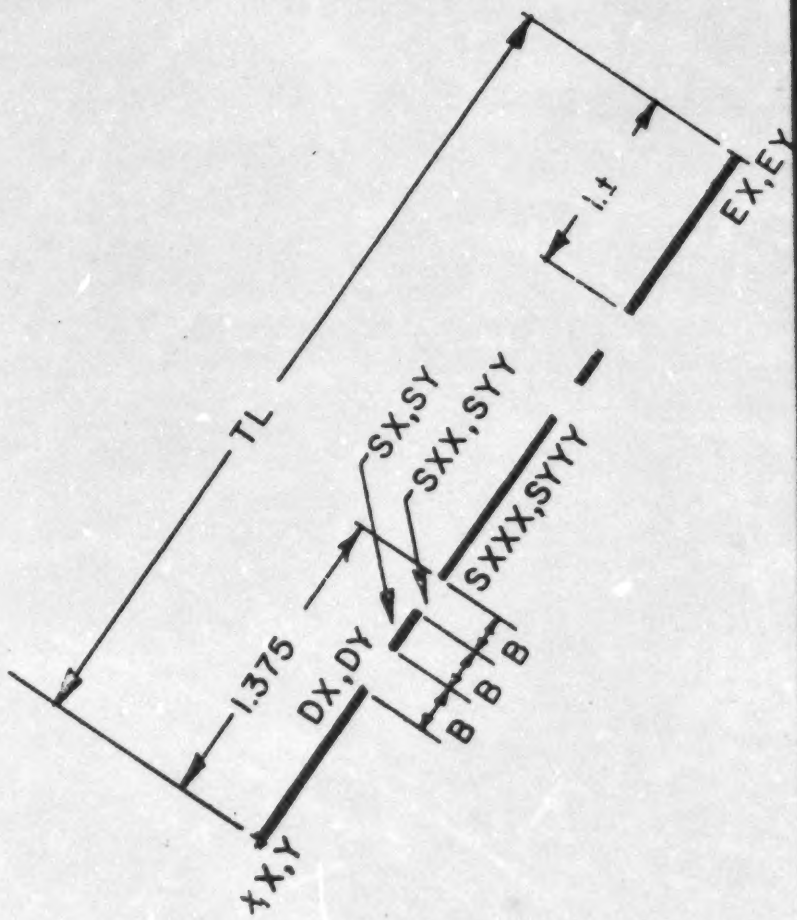
```
100C PROGRAM TO PLOT DASHED LINES
101C (X,Y) ARE THE COORDINATES OF THE BEGINNING OF THE DASHED LINE.
102C (EX,EY) ARE THE COORDINATES OF THE ENDING OF THE DASHED LINE.
110 SUBROUTINE DASHL (X,Y,EX,EY)
115 CALL OFFSET(0.,1.5,0.,1.)
120 B=.125
125 TL=SQRT((EX-X)**2+(EY-Y)**2)
130 ANS=(TL/B)/2.
135 NS=ANS
137 XNS=NS
138 TSL=XNS*B
140 COS(A)=(EX-X)/TL
145 SIN(A)=(EY-Y)/TL
150 TDL=TL-TSL
155 DL=TDL/(XNS+1.)
160 ND=XNS+1.
170 CALL PLOT(X,Y,13)
171 DBX=COS(A)*DL
172 DBY=SIN(A)*DL
173 SBX=COS(A)*B
174 SBY=SIN(A)*B
175 XX=X
176 YY=Y
177 DO 01 J=1,ND
180 DX=DBX+XX
185 DY=DBY+YY
190 CALL PLOT(DX,DY,12)
195 SX=SBX+DX
200 SY=SBY+DY
210 CALL PLOT(SX,SY,13)
220 XX=SX
225 YY=SY
230 01 CONTINUE
235 CALL TTY
245 RETURN
250 END
```



(ANS) is the number of spaces.
(TSL) is the total length of the spaces.
(TDL) is the total length of the dashes.
(DL) is the length of each dash.

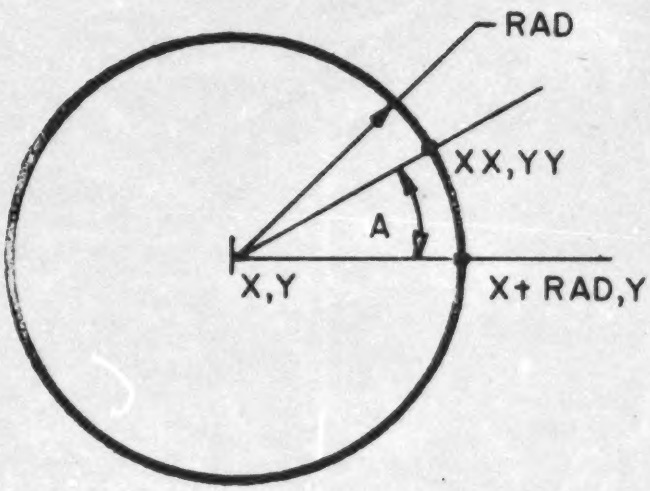
II
2-2

```
100C PROGRAM TO PLOT A CENTER LINE
101C (X,Y) ARE THE COORDINATES OF THE BEGINNING POINT.
102C (EX,EY) ARE THE COORDINATES OF THE ENDING POINT.
103C THE LONG DASHES ARE APPROXIMATELY 1.25 INCHES LONG AND
104C + THE SPACES AND SHORT DASHES ARE .125 INCHES LONG.
105C THE TOTAL LENGTH (TL) MUST BE EQUAL TO OR GREATER THAN 2.375 IN.
110 SUBROUTINE CLINE (X,Y,EX,EY)
115 CALL OFFSET (0.,1.5,0.,1.)
120 B=.125
125 TL=SQRT((EX-X)**2+(EY-Y)**2)
130 TNLSD=(TL-1.)/(1.375)
135 NLSD=TNLSD
137 ANLSD=NLSD
140 TLSD=ANLSD*(3.*B)
145 TLLD=(TL-1.)-TLSD
150 LLD=TLLD/ANLSD
165 COS(A)=(EX-X)/TL
170 SIN(A)=(EY-Y)/TL
175 CALL PLOT(X,Y,13)
180 DBX=COS(A)*LLD
185 DBY=SIN(A)*LLD
190 SSX=COS(A)*B
195 SSY=SIN(A)*B
197 XX=X
198 YY=Y
200 DO 02 J=1,NLSD
205 DX=DBX+XX
210 DY=DBY+YY
215 CALL PLOT(DX,DY,12)
220 SX=SSX+DX
225 SY=SSY+DY
230 CALL PLOT(SX,SY,13)
235 SXX=SSX+SX
240 SYY=SSY+SY
245 CALL PLOT(SXX,SYY,12)
250 SXXX=SSX+SXX
255 SYYY=SSY+SYY
260 CALL PLOT(SXXX,SYYY,13)
265 XX=SXXX
270 YY=SYYY
275 02 CONTINUE
280 CALL PLOT(EX,EY,12)
285 CALL TTY
295 RETURN
300 END
```



(TNLSD) is the total number of long dashes, short dashes and spaces.
(TLSD) is the total length of the short dashes and spaces.
(TLLD) is the total length of the long dashes.
(LLD) is the length of each long dash.

```
100C PROGRAM TO PLOT A CIRCLE
101C (X,Y) ARE THE COORDINATES OF THE CENTER OF THE CIRCLE
102C (RAD) IS THE RADIUS OF THE CIRCLE
110 SUBROUTINE CIRCLE (X,Y,RAD)
115 CALL OFFSET (0.,1.5,0.,1.)
120 CONV=3.14159265/180.
122 CALL PLOT (X,Y,13)
125 CALL PLOT (X+RAD,Y,13)
130 ANGLE=0.0
135 20 XX=X+RAD*COS(ANGLE*CONV)
140 YY=Y+RAD*SIN(ANGLE*CONV)
145 CALL PLOT (XX,YY,12)
150 IF (RAD-3.)5,10,15
155 5 IF (RAD-1.)6,7,8
156 6 GRAN=15.
157 GO TO 40
158 7 GRAN=10.
159 GO TO 40
160 8 GRAN=5.
161 GO TO 40
162 10 GRAN=6.
163 GO TO 40
164 15 GRAN=3.
165 GO TO 40
170 40 ANGLE=ANGLE+GRAN
175 IF (361.-ANGLE) 25,25,20
180 25 CONTINUE
185 CALL PLOT (X+RAD,Y,12)
190 CALL TTY
200 RETURN
205 END
```

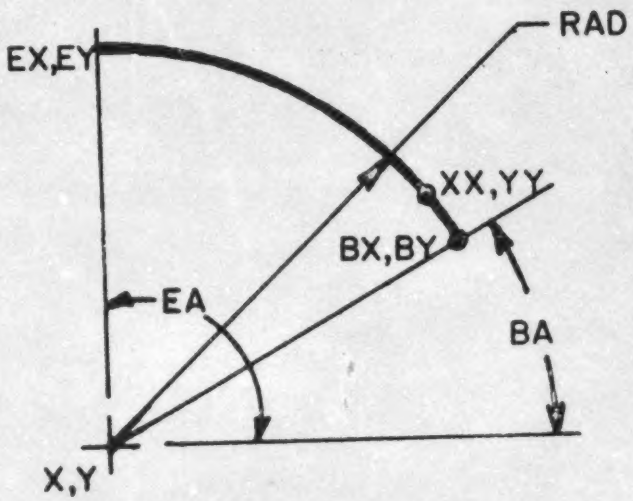


(CONV) converts the angle degrees to radians.

(NOTE) (GRAN) provides a means of changing the angular location of (XX, YY) so as to generate a smoother circle.

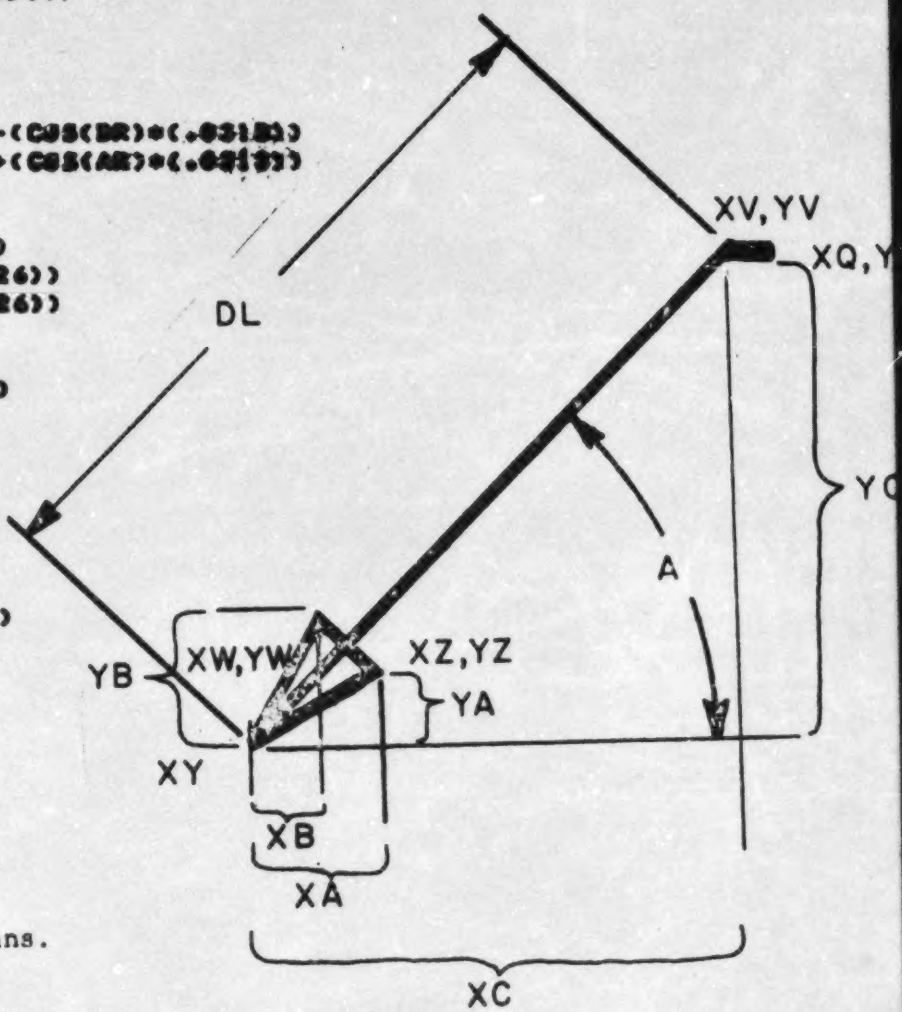
```
ARC        14:25   THURS 07-06-71

100C PROGRAM TO PLOT AN ARC
101C (X,Y) ARE THE COORDINATES OF THE CENTER OF THE ARC.
102C (RAD) IS THE RADIUS OF THE ARC.
103C (BA) IS THE ANGLE THAT THE BEGINNING POINT MAKES WITH
104C + (+X) AXIS MEASURED COUNTERCLOCKWISE.
105C (EA) IS THE ANGLE THAT THE ENDING POINT MAKES WITH THE
106C + (+X) AXIS MEASURED COUNTERCLOCKWISE.
110 SUBROUTINE ARC (X,Y,RAD,BA,EA)
115 CALL OFFSET (0.,1.5,0.,1.)
120 CONV=3.14159265/180.
122 CALL PLOT (X,Y,13)
125 ANGLE=BA
126 BX=X+RAD*COS(ANGLE*CONV)
127 BY=Y+RAD*SIN(ANGLE*CONV)
128 CALL PLOT(BX,BY,13)
135 20 XX=X+RAD*COS(ANGLE*CONV)
140 YY=Y+RAD*SIN(ANGLE*CONV)
145 CALL PLOT(XX,YY,12)
150 IF (RAD-3.)5,10,15
155 5 IF (RAD-1.)6,7,8
156 6 GRAN=15.
157 GO TO 40
158 7 GRAN=10.
159 GO TO 40
160 8 GRAN=6.
161 GO TO 40
162 10 GRAN = 6.
163 GO TO 40
164 15 GRAN = 3.
165 GO TO 40
170 40 ANGLE = ANGLE+GRAN
175 IF (EA-ANGLE)25,25,20
180 25 CONTINUE
185 EX = X+RAD*COS(EA*CONV)
190 EY = Y+RAD*SIN(EA*CONV)
195 CALL PLOT (EX,EY,12)
200 CALL TTY
210 RETURN
215 END
```



(CONV) converts the angle from degrees to radians.
(GRAN) provides a means of changing the angular location of (XX, YY) so as to generate a smoother circle.

```
100 PROGRAM TO PLOT LEADER LINE
110 (X,Y) ARE THE COORDINATES OF THE TIP OF THE ARROWHEAD.
120 (A) IS THE ANGLE THAT THE LEADER MAKES WITH THE (+X) AXIS
130 + MEASURED COUNTERCLOCKWISE.
140 (DL) IS THE LENGTH OF THE LEADER LINE.
20 SUBROUTINE LEADR(X,Y,A,BL)
30 CALL OFFSET(0.,1.5,0.,1.)
40 AR=.01745*A
50 CALL PLOT(X,Y,13)
60 B=90.-A
70 BR=B*.01745
80 XA=(COS(AR)*(.1875))-(COS(BR)*(.0313))
90 YA=(SIN(AR)*(.1875))+(COS(AR)*(.0313))
100 XZ=XA+X
110 YZ=YA+Y
120 CALL PLOT (XZ,YZ,12)
130 XB=XA+(SIN(AR)*(.0626))
140 YB=YA-(COS(AR)*(.0626))
150 XW=XB+X
160 YW=YB+Y
170 CALL PLOT (XW,YW,12)
180 CALL PLOT (X,Y,12)
190 XC=(COS(AR)*BL)
200 YC=(SIN(AR)*BL)
210 XV=XC+X
220 YV=YC+Y
230 CALL PLOT(XV,YV,12)
240 XQ=XV+.125
260 CALL PLOT (XQ,YV,12)
270 CALL TTY
300 RETURN
310 END
```



(AR) is the angle (A) in radians.

```
WAT
100C PROGRAM TO PLOT DIMENSION LINE
110C (X,Y) ARE THE COORDINATES OF THE LOWER LEFT HAND ARROWHEAD
120C + POINT OF THE DIMENSION LINE
130C (A) IS THE ANGLE THAT THE DIMENSION LINE MAKES WITH THE
140C + (+X) AXIS MEASURED COUNTERCLOCKWISE
150C (DL) IS THE LENGTH OF THE DIMENSION LINE IN INCHES
160C MEASURED FROM THE TIP OF ONE ARROWHEAD TO THE TIP OF THE OTHER
170 SUBROUTINE DIMENL (X,Y,A,DL)
180 CALL OFFSET (0., 1.5, 0., 1.)
190 AR = .01745*A
200 CALL PLOT (X, Y, 13)
210 B=90.-A
220 BR = B*.01745
230 XA = (COS(AR)*(.1875)) - (COS(BR)*(.0313))
240 YA = (SIN(AR)*(.1875)) +(COS(AR)*(.0313))
250 IF (DL-.5)10,10,5
260 5 CONTINUE
270 XZ = XA + X
280 YZ = YA + Y
290 CALL PLOT (XZ, YZ, 12)
300 XB=XA+(SIN(AR)*(.0626))
310 YB=YA-(COS(AR)*(.0626))
320 XW = XB + X
330 YW = YB + Y
340 CALL PLOT (XW, YW, 12)
350 CALL PLOT (X, Y, 12)
360 XC = (COS(AR)*DL)
370 YC = (SIN(AR)*DL)
380 XV = XC + X
390 YV = YC + Y
400 CALL PLOT (XV, YV, 12)
410 XD = XC - XA
420 YD = YC - YA
430 XU = XD + X
440 YU = YD + Y
450 CALL PLOT (XU, YU, 12)
460 XE = XC - XB
470 YE = YC - YB
480 XT = XE + X
490 YT = YE + Y
500 CALL PLOT (XT, YT, 12)
510 CALL PLOT (XV, YV, 12)
520 GO TO 15
530 10 CONTINUE
540 XZ=X-XA
550 YZ=Y-YA
560 CALL PLOT (XZ,YZ,12)
570 XB=XA+(SIN(AR)*(.0626))
580 YB=YA-(COS(AR)*(.0626))
590 XW=X-XB
600 YW=Y-YB
610 CALL PLOT (XW,YW,12)
620 CALL PLOT (X,Y,12)
630 XC=(COS(AR)*DL)
640 YC=(SIN(AR)*DL)
650 XV=XC+X
660 YV=YC+Y
670 CALL PLOT (XV,YV,12)
680 XD=XC+XA
690 YD=YC+YA
700 XU=X+XD
710 YU=Y+YD
720 CALL PLOT (XU,YU,12)
```

II
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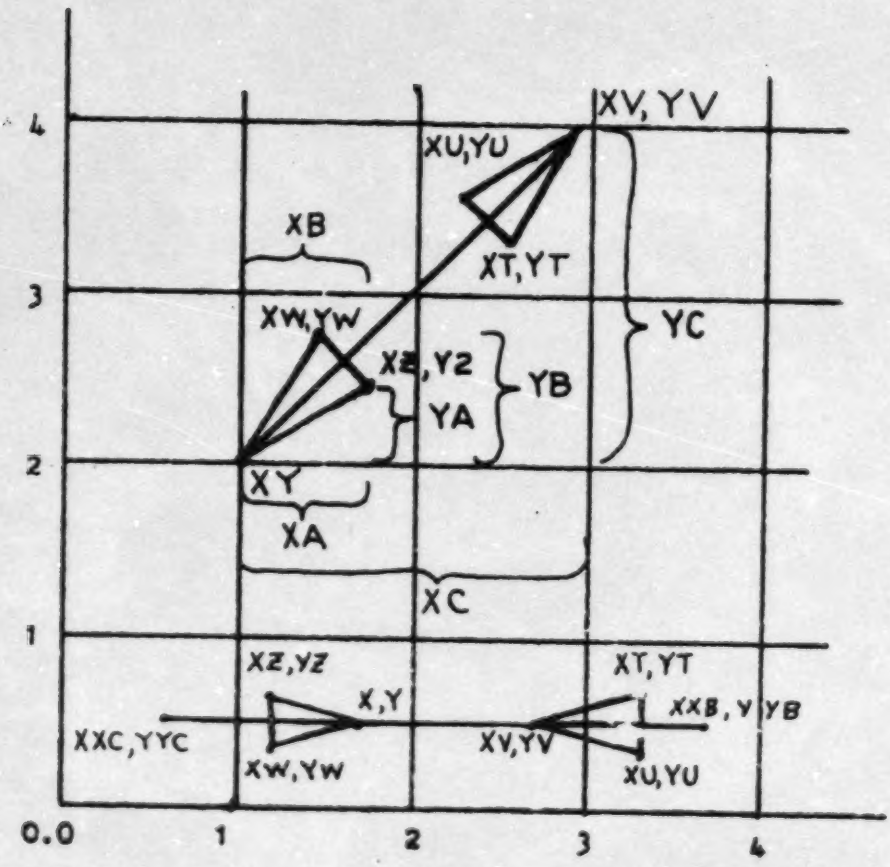
```
750 XT=XE+X
760 YT=YE+Y
770 CALL PLOT (XT,YT,12)
780 CALL PLOT (XV,YV,12)
790 XXA=(COS(AR)*.25)
800 YYA=(SIN(AR)*.25)
810 XXB=XXA+XV
820 YYB=YYA+YV
830 XXC=X-XXA
840 YYC=Y-YYA
850 CALL PLOT (XXB,YYB,12)
860 CALL PLOT (XXC,YYC,12)
870 15 CONTINUE
880 CALL TTY
890 RETURN
900 END
```



(State Use Only)
(1-6)

Project Director Richard Pointer Institution or agency Vincennes University

Proposed Duration: (mos.) 12 months Starting date: 1/1/71 Ending date: 12/31/71

EXPENDITURE BACKING SHEET

ITEMS		COSTS	
		Agency (A)	State and/or Federal (B)
A. DIRECT COSTS			
1. Personnel (include all salaries of professional persons involved in project)	(7-12)		
2. Contractual services (services of clerical persons or nonprofessional staff)	(13-18)	Computer Programming	880.00
3 Employee benefits	(19-24)		
4 Travel	(25-30)		295.80
5. Supplies and materials	(31-36)		539.20
6. Communications (include phone calls, printing . . .)	(37-42)		
7. Properties (rentals or purchase of equipment)	(43-48)	Computer Time Sharing Terminal Purchase Plotter Purchase	5,837.28 1,256.95 3,365.70
8. Facilities	(49-54)		
9. Product production and dissemination	(55-60)		
10. Project evaluation	(61-66)		
B. INDIRECT COSTS	(67-72)		445.74
C. TOTAL COSTS	(73-78)		$12,620.67

State Contribution $10,000.00 Vincennes University Contribution $2,620.67

*Present a more detailed expenditure report on a separate page.

VOC2DS/Form 7